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Laser Transmission Through Membranes Using the Q-Switched Nd:YAG Laser

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Background and Objective: **Many laser centres utilise various transparent membranes during treatment sessions with Q-switched lasers to prevent or reduce tissue splatter, thereby reducing the aerosolised biohazard of cellular debris to operator and laser.**
Study Design/Materials and Methods: **We performed a series of experiments with the Q-Switched Nd:YAG laser, a selection of 11 varieties of membrane and a power meter in order to ascertain which of the membranes was the most effective protector concerning transmission of laser energy. Other mechanical properties such as transparency, strength, ease of application, and flexibility were taken into account.**
Results: **Tegaderm® (overall average 94% transmission), Cling Film® (93%), Bioclusive® (89%), Opsite® (91%), and Microwave Cling Film® (87%) all consistently performed well in pure transmission terms, whereas other membranes tested such as Acetate (74%), Grades of Melinex® (75%, 72%, 75%), 2nd Skin® (74%), and Perspex (68%) were unsuitable as protection.**
Conclusion: **Cling Film® proved to be the best all round membrane. We recommend its use for operator and laser protection against the tissue spatter produced from the Q-Switched Nd:YAG laser. Lasers Surg. Med. 24:48–54, 1999.**

Key words: aerosolised tissue debris; protective membrane; Q-switched Nd:YAG laser

INTRODUCTION

The Q-Switched frequency doubled Nd:YAG laser operating at both 532 and 1,064 nm has seen widespread use in the management of various cutaneous lesions. This unit has developed extensive experience using this laser to treat pigmented lesions and tattoos, having treated more than 800 patients with the laser over a 4-year period since 1992. Tissue splatter from the treated area of skin constitutes a problem to both the operator and to the laser itself and has previously been mentioned by other authors [1] . Cellular debris may leave the patient's skin at high speeds, particularly when treating patients at higher fluences. Not only does the debris constitute a biohazard to the operator, necessitating the use of masks and gloves in addition to the protective eyewear, but it can cause damage to the lens within the laser handpiece (Fig. 1). Many units in the UK utilise a number of transparent membranes held against the lesion in order to protect operator and laser from the cellular debris. We devised a series of experiments which attempted to ascertain which of the commonly used substances performed best in terms of percentage transmission of incident laser energy.

MATERIALS AND METHODS

A Medlite® Q-Switched frequency doubled Nd:YAG laser operating at 1,064 and 532 nm was

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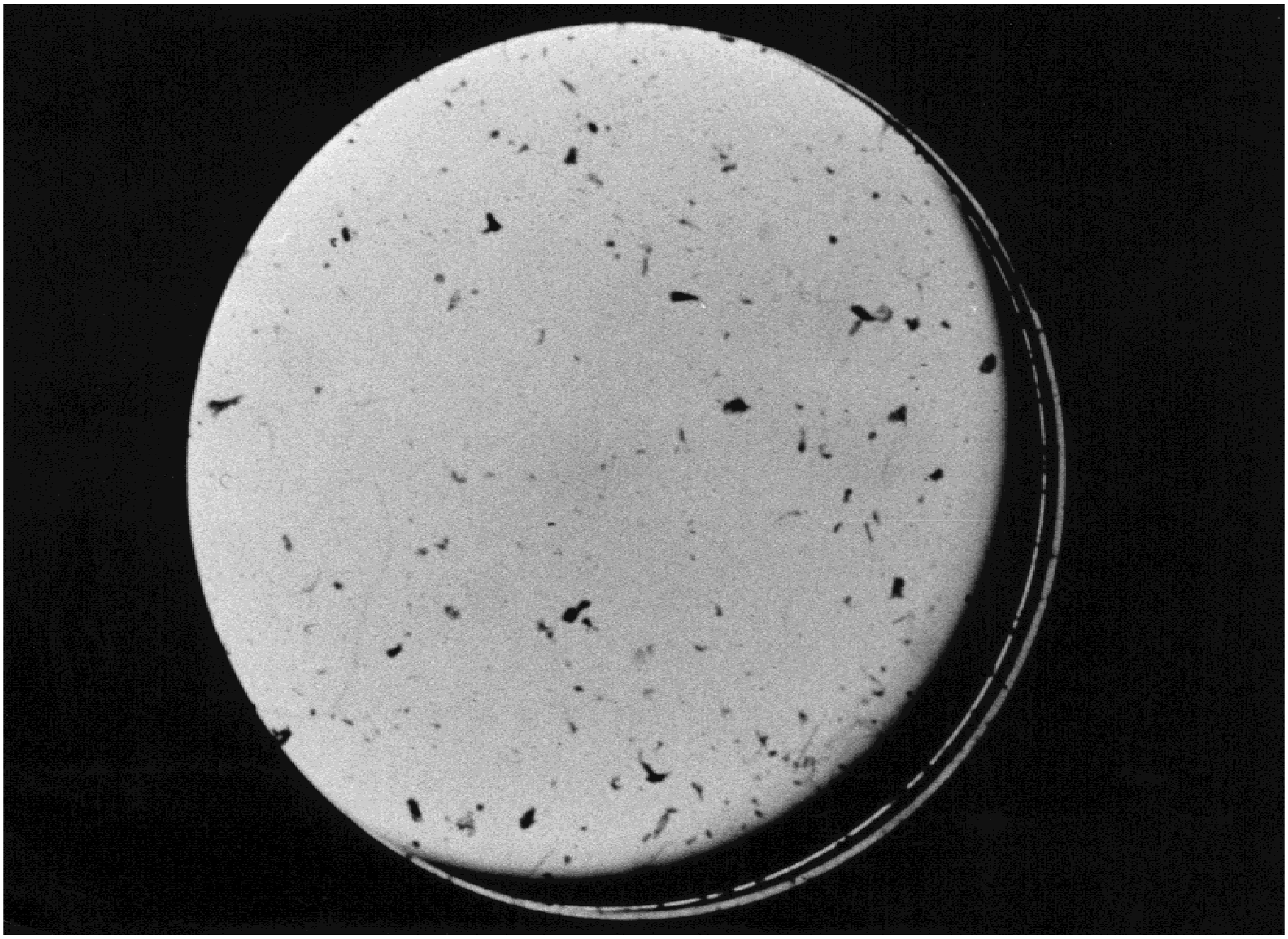

Fig. 1. Lens from Q-Switched Nd: YAG laser handpiece showing cellular debris.

utilised for this series of experiments. The laser handpiece was secured in a clamp above the work surface in the laser suite, at a set specified distance above an OPHIR® laser power/energy meter (model DGHH). The clamp was positioned to hold the handpiece at a specific height such that the interchangeable variable spot size handpieces could be alternated without altering the distance from laser lens to power meter. When in place, the laser was positioned such that the spot was focused on the power meter (Fig. 2).

With laser and power meter warmed to operating temperatures (30 min), a series of membranes was introduced into the well of the power meter to lie on the graphite receptor beneath the laser (Fig. 2). A sequence of exposures was then performed on each of the membranes, varying fluence from 0.5 to 18 J/cm^2, by 0.5 J intervals and spot size (3, 2, and 1.5 mm) until either maximum output was reached or the membranes were tested to destruction. If a particular membrane was able to withstand all the incident energy levels available with the 3 mm spot, the spot size was changed to the 2 mm and then to the 1.5 mm until tested to destruction, as higher fluences were achievable with the smaller spot sizes. The laser was fired at 10 Hz until a peak reading was obtained from the power meter, which was then recorded in tabular form. Because of limitations of specification, it was not possible to subject the graphite disc of the meter to maximum fluence of the laser (18 J/cm^2 at 1.5 mm spot size) without causing damage. The maximum output of the laser tolerated by the disc without damage or impairment of function was found to be 12 J/cm^2 at 1,064 nm and 8 J/cm^2 at 532 nm with 1.5 mm spot size. This still gave adequate information relevant to the majority of clinical situations. All membranes still intact above the safe operating range of the power meter were then tested to destruction without power meter present. Control experiments were performed with the laser at op-

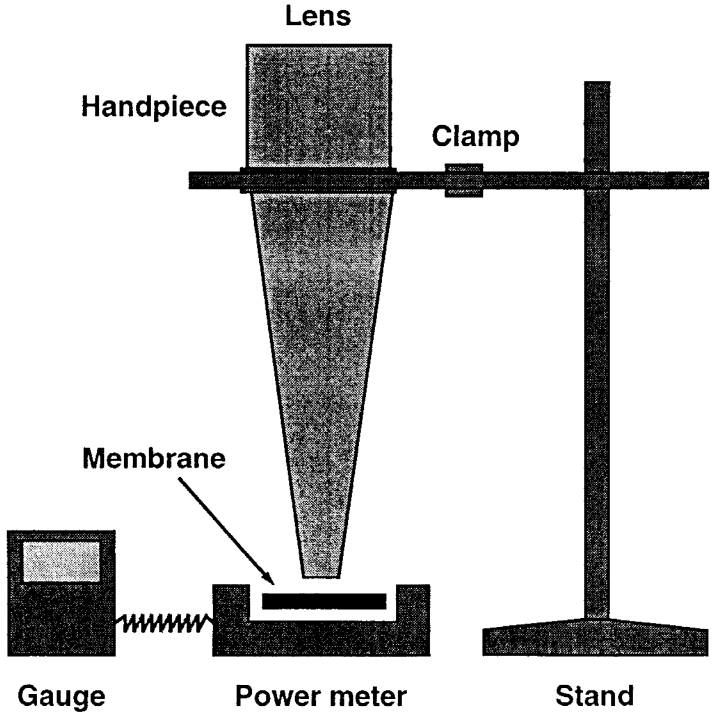

Fig. 2. Diagrammatic representation of the experimental arrangement with the Q-Switched Nd:YAG laser held in a clamp, adjusted to focus on the surface of the power meter, with interposed membrane.

erating temperature, immediately prior to each series of membrane experiments, this procedure being repeated on each separate occasion to ensure accuracy and reproducibilty of recordings. All the experiments were performed under the same standardised conditions of lighting and temperature in the laser suite and were all performed by the same operator to eliminate variables.

Membranes tested in this fashion were: polyvinyl chloride (Cling Film®); polyvinyldene chloride with acetyltributylcitrate plasticiser (Microwave Cling Film®); polyethylene oxide hydrogel (2nd Skin®) Spenco Medical; Opsite® , Smith and Nephew; Bioclusive®, Johnson and Johnson; Tegaderm®, 3M; polyethylene terephthalate (Melinex®) at 36, 96, and 175 um, ICI; Perspex (culture medium bottle); and polyvinylacetate sheet (overhead projection sheet).

Cling Film® is a frequently used transparent food wrap that clings to foodstuffs when applied. It is used extensively in catering to keep food fresh during storage and to help retain moisture while cooking. Due to concerns regarding some plasticisers (the substance that makes food wraps "cling") of migration into food especially when used in microwave ovens [2], a microwave compatible cling film has been produced with an approved plasticiser. It has similar properties to standard cling film but is slightly more robust and does not "cling" as readily. Melinex is the trademark for ICI's range of biaxially orientated transparent films made from polyethylene terephthalate (PET). They are similar in property to Mylar®, a transparent plastic used in sail construction [3]. Melinex is used for applications in a wide variety of industries. It is an ideal base for photographic films and is also used for electrical cable wraps, credit cards, bank and cheque cards. Typical application in packaging of foodstuffs are for coffee and dried foods, confectionery, snackfoods and nuts, liquid packaging, freezer to oven ready meals, and various lidding applications [4]. Available in varying grades from 36–175 um thickness, we chose the upper, lower, and middle of the range for testing.

All results were recorded in tabular form for each membrane for full range of fluences, wavelengths, and spot sizes. Observations regarding relative performance were also made at the time of experiments, with particular note of opacification or destruction of the membrane involved. The ability of the membrane to withstand incident laser energy without destruction was also noted as this represented the ultimate goal of the experiment in terms of protection of operator and laser (Table 1). Any membrane that was perforated or

TABLE 1. Physical Characteristics of Membranes (0.5 to 12 J/cm²) at 532 and 1064 nm, All Spot Sizes

	% Transmission				
Material	1064 nm	532 nm	Opacification*	Flexibility	Protection
Perspex	69	67	1.0 J/cm²	Rigid	Full
Melinex 96u	71	79	1.0 J/cm²	Rigid	Partial
2nd skin	72	76	7.5 J/cm²	Conforms	Full
Melinex 36u	74	69	1.0 J/cm²	Rigid	Partial
Melinex 175u	77	73	1.0 J/cm²	Rigid	Partial
Acetate (OHP)	78	70	1.5 J/cm²	Rigid	Full
Microwave Cling Film	86	88	3.2 J/cm²	Conforms	Partial
Opsite	89	93	2.5 J/cm²	Conforms	Partial
Bioclusive	90	88	3.0 J/cm²	Conforms	Partial
Cling Film	91	95	Nil	Conforms	Full
Tegaderm	94	93	3.5 J/cm²	Conforms	Partial

*Refer to results text for information regarding wavelength and spotsize.

destroyed by the laser could only provide protection to a certain incident energy level and was therefore graded as "partial." An intact membrane implied "full" protection. Flexibility and therefore ease of application of a particular membrane were assessed as "rigid" or "conforming." Calculations of transmission across the membranes were recorded in terms of a percentage when compared to the controls.

RESULTS

All results are recorded in Table 1. These figures were obtained by arithmetical calculation. Percentage transmission was calculated through each membrane tested in comparison to the control figures. These figures are shown as an average of all the results obtained for each membrane at the full range of energies for both wavelengths (532 and 1,064 nm). Other performance-related observations and relevant information are included below.

Polyvinyl Chloride (Cling Film®)

Polyvinyl Chloride (Cling Film®) withstood the incident laser energy at all spot sizes, wavelengths, and fluences. It remained intact at maximal registered energy density (12 J/cm² at 1,064 nm, 8 J/cm² at 532 nm) and indeed at maximal fluence (18 J/cm²) without meter present.

Polyvinyldene Chloride With Acetyl Tributyl Citrate Plasticiser (Microwave Cling Film®)

Similar to standard cling film, this withstood incident laser energy at all tested fluences at 1,064 nm, but was destoyed at a relatively low level at 532 nm.

2nd Skin®

This hydrogel dressing had characteristic properties on testing compared to the other membranes; the peak power recorded occurred after 10 seconds of continuous laser exposure. There was a similar period of time before the OPHIR meter decayed to zero. This robust membrane remained intact at all incident laser energies, although there was a tendency for the gel to bubble and opacify at fluences over 7.5 J/cm² at 1.5 mm spot size at 1,064 nm. This rendered the target area beneath the gel dressing difficult to distinguish.

Opsite®

A vapour permeable adhesive film dressing, this was able to withstand all fluences at 532 nm. It opacified very quickly at low incident levels of laser energy density (2.5 J/cm²) with all spot sizes at 1,064 nm. It was thereafter very quickly destroyed as the laser fluence was increased. Opacification again obscured the target area on the power meter.

Bioclusive®

With similar properties to Opsite®, this dressing behaved as expected; it withstood all incident energy at 532 nm, but there was swift bubbling, opacification (3.0 J/cm²), and destruction (4.5 J/cm²) at relatively low laser fluences at 1,064 nm.

Tegaderm®

Another semipermeable dressing with similar properties to Opsite® and Bioclusive®, this was opacified at low levels of fluence. It survived maximal energy density (4.8 J/cm²) at 3 mm spot size at 1,064 nm, but was opacified and bubbled at

5.5 J/cm^2 at 2 mm spot size and 3.5 J/cm^2 at 1.5 mm spot size. It survived maximal fluences at 1.5 mm spot size and 532 nm.

Melinex®

All grades performed similarly; opacification occurred at very low fluences at both wavelengths, and destruction followed soon after. Each of the films opacified early (at 1.0 J/cm^2), thus obscuring the power meter from the incident laser energy. This resulted in a peak reading (as measured on the meter) prior to opacification followed by a swift decay as opacification occurred.

Perspex®

Part of a culture medium bottle (1 mm thickness clear perspex) was subjected to incident laser energy at varying fluences, spot sizes, and wavelengths. It became apparent that in order to attain peak power, the laser light could not rest on one particular area of the perspex for more than six laser pulses before opacification occurred. Even with the introduction of movement (the perspex was adjusted so that the incident beam was not stationary for more than 6 pulses), opacification and clouding of the plastic occurred at fluences of only 1.0 J/cm^2 at both wavelengths.

Polyvinylacetate sheet (overhead projector sheet)

Clouding and opacification occurred early in the series of experiments, between 1.0 and 2.0 J/cm^2 at all fluences and both wavelengths. Thereafter there was difficulty in reading the power meter values as a transient peak was obtained that was maintained for only a few pulses before gross opacification and rapid decline in reading occurred.

DISCUSSION

The nonlaser beam biohazard of high velocity cellular debris from the skin surface of patients is difficult to quantify but certainly constitutes a significant concern in this unit. Previous authors have briefly mentioned the hazard constituted by cellular debris using the Q-Switched Ruby and Nd:YAG lasers [1], and a recent abstract has alluded to similar concerns to ours using the Q-Switched Alexandrite Laser [5]. We are unaware of any published experimental work on operator protection by membrane with the Q-Switched Nd:YAG laser used for tattoo or pigmented lesion clearance. For the operator, there are physical concerns—small tissue flecks at high speed are a painful hazard when striking the face or hands. As protective eyewear is mandatory when operating the laser, tissue debris does not constitute a perceivable ocular hazard in these circumstances. It is our policy to wear gloves when using the laser, thus reducing any biohazard from potential debris impact. As far as we are aware, there have been no recorded instances of hepatitis or HIV transmission during laser treatment of lesions at high fluences with the Q-Switched Nd:YAG laser from operator to patient, or vice versa. Aerosolised cellular debris and the presence of a bleeding skin surface in some patients must constitute a theoretical risk of transmission of the above as well as other diseases, which in tattoo patients may be higher than in a similar nontattooed group [6]. Protective eyewear, gloves, and a surgical mask are therefore recommended to minimize operator risk.

The laser itself is also potentially at risk from the high velocity cellular debris from the tissue surface. Figure 1 shows the debris that can accumulate during therapy on the lens, which is part of the handpiece. Given time, this debris could constitute a significant problem in terms of reduction in efficiency of the laser. On close inspection, it would appear that some of the debris has chipped the lens, which not only illustrates the significant potential biohazard to operator, but also that the optical properties of the laser handpiece may be irrevocably altered given time and sufficient damage. Some manufacturers provide plastic cones or discs fitted to the laser handpiece to capture debris. Many of these are cumbersome, obscure the target, “fog” easily, and do not protect the laser lens. There is clearly a need, therefore, to utilise a system whereby both operator and laser may be protected against the perceived problems created by this aerosolised debris produced during therapy. The ideal system should have a number of properties conferring protection without seriously inconveniencing operator or patient or reducing laser efficiency during therapy. The substance should be transparent so as not to obscure target from the operator. It should be robust enough to withstand transmission of laser energy at a range of fluences, spotsize, and wavelengths without opacification or destruction. There should be minimal spectral reflection, scatter, or absorption of laser energy on contact with the surface of the protecting layer. Ideally the substance should be easily and swiftly

applied with minimal discomfort to patient, should be flexible and conforming such that curving and irregular body surfaces may be taken into account. The protector should also constitute a barrier among patient, operator, and the laser. The barrier should be able to withstand the impact of airborne cellular debris and must also have the ability to contain tissue fluid and debris (blood, serous fluid, etc.) and isolate this from the external environment. Financial concerns are a significant factor for all health service providers, and thus a cheap but effective method of protection should be preferred.

From our series of experiments, a few conclusions can be made relating to the suitability for protection of the various substances tested during use of the Nd:YAG laser. Some substances tested were clearly unsuitable as candidates for cell debris protectors. The varying grades of Melinex, the acetate sheet, and the perspex were unable to withstand the effects of the incident laser at relatively low fluences at either wavelength. Opacification occurred quickly, thereby obscuring the target and forcing cessation of the experiment. They also demonstrated a significant percentage loss of laser power across the interface, which would have clinical implications in reducing effectiveness and prolonging treatment. These substances were comparatively rigid, did not conform to body contour, and were relatively expensive.

The three semipermeable dressings, Opsite®, Bioclusive®, and Tegaderm®, had similar properties to each other. Although they performed well in terms of percentage transmission, a number of features were apparent that made them less preferable. Opacification and hence increased absorption of laser energy by the membrane was a feature of all the dressings at low fluences, again obscuring target and requiring cessation of the experiment. By virtue of their adhesive backing, the dressings easily conform to body surfaces and are able to contain serous fluid and blood during therapy. On removal from the skin surface, however, there is significant discomfort produced by the close adherence of the adhesive dressing to the skin. Many patients may find this additional discomfort unacceptable following an already uncomfortable procedure.

2nd Skin® hydrogel dressing (Spenco) is utised in many clinical situations and certainly has a role to play with superficial burns and skin abrasions. By virtue of its hydration, it produces a marked cooling effect when placed on the skin surface, which is related to rapid heat conduction away from the site. This unit utilises this dressing for post-treatment analgesia on numerous laser-treated lesions, in much the same way as other cooling agents and ice packs are used. Although the physical properties confer clinical advantages in some circumstances, it is this very property that reduces the transmission of laser energy through to the power meter. Some 25–30% of the incident energy was lost in transmission through this dressing during the experiments. The meter readings for this dressing were notable in that the peak power recorded took some 10 seconds to attain and a similar time to decay to zero on removal of the stimulus. We feel that this delay to peak power is a function of the heat dissipation properties of this dressing. Although it is thick and robust and protects against spatter, there is significant obscuring of target, thus slowing a treatment session. Although some of its properties make it an ideal dressing for post-treatment lasered areas, burns, and abrasions, it appeared unsuitable as a protector against tissue debris.

The two types of Cling Film® used appeared most suitable in all respects of the criteria set for tissue debris protection. They have inherent physical characteristics that render them ideal for this purpose; they are easily applied, conforming, transparent, pain-free on removal, and cheap. They performed well in terms of transmission capabilities (Table 1) and were able to protect the operator from tissue fluids and aerosolised tissue debris. Of note was that the Microwave cling film is more brittle and slightly less conforming than the standard cling film and when used in a clinical situation has a greater tendency to shatter and split at the higher fluences.

Our best results show a loss of between 5% and 10% of incident laser energy when applied through a membrane. One must assume that this will either be reflected or absorbed by the membrane. Reflected laser energy should not constitute a significant biohazard to operator or patient if suitably protected as the energy levels involved are low. If energy is absorbed by the film and transformed to heat in the material, the material tends to opacify. Laser energy would appear, therefore, to be dissipated rapidly away from the incident site in the majority of dressings, as there is no opacification noted within the clinical therapeutic range. The clinical corollary is that there is no local heat accumulation and potential patient compromise if the material remains transparent.

Criticisms may be levelled at this series of experiments as they were performed in an in vitro

situation with the laser handpiece clamped stationary above the membrane. In practice, the laser handpiece is moved continually and problems of opacification may therefore not obscure the target. The ideal membrane, however, would not opacify at all, even at the highest fluences, thus negating the argument. Opacification itself implies laser energy absorption by the membrane, thereby reducing percentage transmission to the target and reducing efficiency of treatment.

CONCLUSION

Although none of the membrane types were ideal in all aspects of physical and laser resistant properties, we found that the ordinary polyvinyl chloride Cling Film outperformed all other candidates in terms of protection from tissue debris and transmission, at a range of clinically applicable fluences, spot sizes, and wavelengths. We therefore advocate its use in clinical situations with the Q-Switched Nd:YAG laser, but would recommend that operators are aware of potential power loss through the membrane and adjust their treatment regime accordingly to more precisely control laser energy delivered to a particular target area.

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